EAI

ELECTRONIC ASSOCIATES, INC.

690 HYBRID COMPUTING SYSTEM

THE GROWTH of sophistication in all fields of scientific investigation has placed increasing demands on the development of advanced techniques for scientific computation and simulation. Hybrid Computation has developed, in the past several years, as the form of computation and analysis required to meet this challenge. □ Using the best of both analog and digital techniques, Hybrid Computation has been able to resolve many complex programs that were impractical to approach by either former discipline alone. This has been clearly demonstrated in the aerospace industries, where the need first arose, and where a high level of sophistication has developed in the use of hybrid techniques. Other areas of scientific and engineering endeavor have increasingly recognized the power of hybrid computation, and a broad spectrum of familiarity with the subject has developed as a function of individual experience. □ This brochure is primarily a description of the EAI 690 Hybrid Computing System, an integrated, third-generation hybrid computer. It presents the equipment and software features that make hybrid computation more practical, more economical and faster than other computational forms. It briefly describes some applications, and the variation in system configuration required for the applications of several scientific disciplines. □ For the reader who wishes more background material or more detailed discussion of applications, EAI has prepared a brochure on Hybrid computation, along with other brochures describing typical 690 systems for various industrial, educational, and scientific fields. There are also many Applications Reference Library articles that provide in-depth discussion of specific applications.

Page 2-3	The 690 Hybrid Computing System
Page 4	The 680 Analog / Hybrid Computer
Page 5	The 640 Digital Computer
Page 6-7	The 693 Hybrid Interface
Page 8-9	Software
Page 10	Applications in: Aerospace/Education
Page 11	Applications in: Bio-medical Engineering / Chemical Processing
Page 12	EAI Support Services

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THE EAI 690 HYBRID COMPUTING SYSTEM is a medium-scale, general purpose engineering and scientific research and design tool. Its primary function is to aid in analyzing dynamic physical systems and computing solutions under different specific conditions. Since the 690 is a general purpose computing system, it is widely adaptable in application, and provides engineering and scientific data in the most useful and meaningful form possible, either graphical or tabular or both.

On a practical level, the 690 functions as the least-cost, least-time route to solution of complex problems. In many fields the performance gain in time of a hybrid system has been as high as 600 to 1 over digital computing techniques. Often it provides the only means to solve problems that could not be resolved in any other fashion.

The reasons for this high level of value in performance stem from the Hybrid configuration of the 690. In no sense is it just an analog computer linked by a data converter to a digital computer. It is a system with properties that cannot be derived directly from its elements, nor considered simply as the sum of its parts.

The parts of the system are certainly important, and there are major characteristics that a Hybrid Computer shares with either an analog or digital machine. For example: an analog performs continuous integration; a digital can do numerical integration; while a hybrid can perform either or both of these. The unique characteristics of the Hybrid Computing System lie in the area of inter-machine communication. The EAI 680, which is the analog portion of the 690, is in itself a basic Hybrid. The patchable logic section provides control functions both for computing elements and display devices. It is capable of logical operations and can perform a basic level of data reduction and storage. Most important, its I/O structure is designed for hybrid communication.

The EAI 640 Digital Computer in the Hybrid System also has a very flexible I/O and interrupt structure designed for Hybrid functions. These two features, which are standard in the basic computer give the 640 the efficient communication capability necessary for optimum performance in a Hybrid System.

Inter-machine communication is expedited by the control and data interface, which is able to generate its own priority interrupts and order the exchange of data for maximum efficiency and program synchronization. Direct interrupt, sense, and control lines terminated on the 680 patch panel through the control interface add a further dimension to the communication, so that the high-speed logic in the 680 can be used for supplemental decision-making or steering.

The sense, control and interrupt lines provide an efficient interchange of data and control information that is used for continuous monitoring, diagnostics and program up-dating. They enable the 640 to maintain control of modes of operation, vary parameters and be informed of events and conditions within the total system.

Hybrid software is the key to optimum usage of hardware features. Since the EAI 690 is a *standard,* integrated Hybrid Computing System, the software has been developed as a package of *standard,* integrated programming procedures that are usable with any 690 system.

In addition to the obvious advantages of pre-testing and continued maintenance of software, 690 users may expect to benefit from constant updating through experience of users and of the EAI Computation Centers. Of further significance, EAI standard software has been able to go beyond the conventional usage of FORTRAN to aid in problem preparation, set-up and check-out. Typical of this is operations software such as the HYTRAN Operations Interpreter, a problem-oriented language for on-line interactive preparation, set-up, control, monitoring and execution of hybrid operations, that ensures maximum programming flexibility while bringing the scientist or engineer closer to his model.

In summary, the EAI 690 Hybrid Computing System is a standard integrated computing system that provides:

- ☐ Programming economy through optimum use of computation and analysis techniques.
- ☐ Automation of time-consuming operations such as set-up and debugging.
- ☐ The ability to simulate continuous or discrete dynamics and provide parallel computation coupled with high-speed, precision arithmetic.
- ☐ Direct, interactive operator communication with the program through both analog controls and hybrid software during operations.
- ☐ Digital function manipulation.
- ☐ Efficient inter-machine communications with self-generated interrupts and priority levels.

THE EAI 680

THE ANALOG portion of the EAI 690 Hybrid Computing System is the EAI 680 Analog/Hybrid Computer. This is a medium scale, 10 volt, all solid-state, 156 amplifier analog computer specifically designed for either stand-alone operation or as an integral part of an EAI Hybrid System.

Used by itself, the 680 is capable of modest hybrid programming, as well as simulation of physical systems and sophisticated analog computation. All mode selection, time scale selection, and computing component control is accomplished by logic signals. A sizeable complement of general purpose logic gates, registers, counters and digitally controlled analog switches allow decision making, data reduction, timing, and binary or coded decimal storage functions to be accomplished directly in the 680.

Dynamic characteristics permit repetitive and iterative operations using analog memory, at a rate in excess of 2 KHz, without significant dynamic error or phase shift in either linear or non-linear computing elements. Crosstalk is 80db down at 10 KHz, so that high frequency signal components do not interfere with the operation of computing elements such as comparators.

In a hybrid configuration, these features become the basis for high speed inter-machine communications. There are 29 programmable Control operations in the 680 which are directly accessible for digital or interface control. A unique interrupt, status and fault word structure is built into the computer to signal significant program status information, independent of the program patching. In addition to these, there are patchable control lines with reset access and both direct sense and interrupt lines with ordered priority that terminate on the 680 patch panel. This allows the programmer to establish problem-oriented functions with subroutines written in the simplest and most direct fashion. Analog-to-digital and digital-to-analog data conversion lines are separately terminated on the patch panel for direct connection to analog computing components selected by the programmer. These channels are separate and distinct from the 120 trunk lines that are available at the patch panel, thus leaving the trunks open for inter-console information exchange.

The dynamic logic in the 680 console is synchronized at a 1 megahertz clock rate for programming ease. General purpose gates are asynchronous with a 40 nanosecond propagation delay per decision. By using this built in, high-speed logic in a hybrid system, many control and decision functions are simplified and status signals, tests, special interrupts and other sense and control information can be directly transmitted through the control interface to and from the 640 digital computer. This ability can be used to simplify programming and minimize the program time commitments on the part of the digital computer.

Analog display devices are synchronized with the 680 program with separate trunking facilities for all control and signal channels for both analog output display, and digital timing and signal structure display. Included in these display peripherals are: a four-trace monitor scope with accessory camera facilities; an 8-channel direct-writing oscillograph; an X-Y plotter; and an 18 channel display scope with 4 simultaneous coded trace display capabilities.

120 coefficient potentiometers can be digitally set under control of either the analog control panel or the digital computer, and re-calculated settings can be entered by inter-machine communication. In addition, the analyst can interject his own inputs at any time, either manually through the analog computer, or by remote station typewriter communication with the digital computer.

A summary of highlight features in the 680 essential to hybrid computation includes:

- ☐ Wide bandwidth integrators and multipliers.
- ☐ Microsecond electronic mode control with all modes controllable from logic signals as well as manually.
- ☐ Independent mode control and time-scale selection of all integrators permitting accurate multi-speed, and compressed time-scale, iterative hybrid operations.
- ☐ Track-store units with extremely low dynamic tracking error and exceptionally low drift in store.
- ☐ Fully shielded patching system combined with 10 volt reference and low impedance circuitry for exceptionally low crosstalk, providing high performance in the large class of hybrid problems where there are numerous step changes in the analog program due to electronic switching.

THE DIGITAL section of the EAI 690 is the EAI 640—a high speed, parallel word, stored program digital computer with a flexible input/output structure that permits convenient integration to a hybrid environment. All instructions and data words contain sixteen bits plus a bit that is used for memory protection. The basic computer uses only four input/output instructions for transfer of data and control words, plus a pair of Record Input/Output instructions for block transfer of data. A flexible interrupt system is included in the basic 640 to provide a general purpose interrupt capability which allows the programmer a choice of interrupt priorities and actions. This interrupt capability is expanded in the linkage between the analog and digital computers when the 640 is operating in a hybrid computing system. A Direct Memory Access Channel can be added to allow high speed input/output with intermixed computation on a cycle stealing basis. The hybrid software package provided with the 640 requires a basic core storage of 8K. The memory is easily expanded to 16K or 32K. Arithmetic for the 640 features add, subtract, multiply, divide, and square root as standard hardwired functions. Advanced micrologic circuitry makes the EAI 640 a third generation computer combining reliability with high speed logic.

The following features are of particular importance when the 640 is operating in a hybrid configuration.

Single Word Mode Input/Output

The basic computer has two single word input/output instructions—Data In and Data Out. These provide a 16 bit parallel word transfer between the external device and the accumulator. With each instruction a Device Number from 0 to 64 is used to address the appropriate device. This mode permits many instructions to be executed between data transfers, and is the prime means for Control communication in hybrid operation.

Record Mode Input/Output

These two instructions—Record In and Record Output—cause a 16 bit parallel word transfer directly between core memory and a specified device on the standard data channel. When operating in the Record Mode, the running program is halted and the processor devotes full time to information transfer from or to a peripheral device. This mode of input/output is generally used in communication with devices having a high transfer rate. Typical use would be to transfer a block of data to digital-to-analog converters.

Interrupt Feature

The interrupt system allows the programmer a choice of interrupt priorities and action. As the name implies, the interrupt system can free the computer for computation between device service cycles without burdening the software system program with extensive static testing. There are 12 levels of interrupt priority, four levels for use with the standard I/O channel. Within these four levels, 64 unique interrupt locations are available for device servicing.

Direct Memory Access Channel

This optional feature operates on a cycle stealing basis and allows computation to continue intermixed with I/O operations. It is another means for performing block data transfer in a hybrid program.

Peripherals

Using the 640 in a hybrid configuration requires the following minimum complement: 8K computer, teletypewriter with paper tape reader/punch. Card reader, card punch, line printer, magnetic tape, disk storage unit, and interval timer are also available.

Programming Systems

The 640 programming system is designed to provide the user with capability for all-digital problem solutions as well as for hybrid computation. Digital programs include ASA Standard FORTRAN IV, a symbolic assembler, a librarian, a sub-routine library, and program check-out aids. For a hybrid environment the following programs are available: HYTRAN Operation Interpreter, Hybrid FORTRAN, Hybrid Debug, Hardware Diagnostics and a Hybrid Sub-routine Library which includes function generation, function storage and function playback.

THE 693 HYBRID INTERFACE

IN HYBRID COMPUTATION, control of the overall program is normally considered to reside with the digital computer. This is true in the sense that the stored program exists in digital memory, and run-time commands originate through execution of the stored program.

However, a major consideration in Hybrid computation is the differing time orientation and program function assigned to the analog and digital domains. The analog portion of the program is usually time-based with simultaneous activities occurring in parallel and representing the dynamic interactions of a physical system. The digital computer, on the other hand, processes all operations sequentially without reference to time, performing activities that can be represented by numerical manipulations. Either an external clock or synchronization by an event (or both) is used to match the two in a total program.

Another major consideration is the requirement for a single device, the 640 Digital Computer, to "talk" with many devices such as the separate computing elements in a 680 analog computer and, in larger systems, to as many as six analog computers.

As a result, the EAI 693 Communications Interface is allocated the role of co-ordinating the exchange of information about equivalent status and conditions as well as converting data in two-way exchange between the analog and digital computers. To do this, the 693 can interrupt the 640 program command structure on a special purpose as well as general basis when the analog portion of the program has priority, and steer digital commands and data to the appropriate analog console and device.

In performing its role as nerve center of the hybrid system, the 693 Communications Interface provides two major functions: monitoring and control and high speed data transfer.

Monitor and Control Functions
The EAI 693 provides the hardware to handle all general overhead and housekeeping functions expeditiously. This greatly minimizes programming and processing time by reducing the number of required instructions for the 640. Data management is also handled largely by the interface equipment saving much bookkeeping especially in processing interrupts. These features further allow better usage of core memory and a simplification of software programs, as the number of housekeeping instructions are reduced.

There are two levels of Monitor and Control activity in the 693. The first is hardwired, requires no patching and performs all functions required for automatic set-up, check-out and general operation of up to six 680 consoles. These functions include: Analog component selection and read-out / Potentiometer value selection and setting / Analog Mode control / Logic Mode control / Integrator Time Scale control / Function relay control Comparator state read-out / Console selection / 680 Console Status read-out / Fault word read-out.

All these functions are under direct program control using the standard instruction repertoire of the 640. This makes check out inherently simple using standard debugging routines.

The second level provides logic control through patchable buffered control, sense, and interrupt lines. These provide single bit logic communication between the 640 and the 680 computers. The system provides 16 control bits, 8 sense bits and 8 interrupt bits. In addition to the single bit transfer mode, any of these groups can be transferred in parallel.

A general purpose interrupt capability consisting of eight interrupts which connect to the 640's external priority interrupt system permit direct intervention of 640 operation from the control logic section of the 680 patch panel. A masking capability is also provided to enable/disable these general purpose interrupts, and other key interrupts as well, according to the mask bits issued. This mask information can be loaded or stored by the 640 commands. With the ability to mask out interrupts, unwanted interrupt signals generated by a 680 which is at the time not being used for hybrid computation, will not disrupt 640 operations.

The control lines are resettable through flip-flops by command from the 640 or by logic information developed within the 680 program. Through the logic level control, event level communication between the analog and digital programs within the Hybrid Computer complex is accomplished.

High Speed Data Transfer
The 693 linkage provides high speed data transfer between the 640 and the 680 by means of an analog-to-digital converter with its associated multiplexer and optional sample/hold units, and of Digital-to-Analog converters or Digital-to-Analog multipliers. The system incorporates features which minimize the number of digital instructions required to produce this information transfer while maintaining the programming flexibility necessary in a hybrid system. Instructions are provided to implement the five basic modes of data transfer as follows:

Analog to Digital Transfer
Random channel selection and conversion.
Sequential selection and conversion of a block of analog channels.
Repeated conversions of a single analog channel.

Digital to Analog Transfer
Random channel selection and loading.
Sequential Selection and loading a block of D/A channels.

The operator can command all individual channel transfers or block transfers by using the single word I/O instructions of the 640. He can also command block transfers using Record I/O instructions or the optional Direct Memory Channel. In addition to the data conversion capability, there is provision for various methods of sampling the analog input channels and updating the analog outputs of the D/A channels either under digital computer control or under logic control from the analog console. Through this latter feature, the data conversion system is provided with another means for synchronization of the analog and digital portions of the hybrid program.

To summarize then:

- ☐ Extensive decoding and storage is provided in the interface for maximum system efficiency;
- ☐ Primary control is allocated to the digital computer to fully exploit its diagnostic and programmable facilities;
- ☐ Analog override is provided in most instances to facilitate program synchronization and to prevent the destruction of volatile data;
- ☐ Comphehensive system status information is made available to permit the digital computer to determine its next course of action rather than always calling for programmer intervention to analyze non-informative interrupts.

690 Hybrid Programming System
A Hybrid software system must provide efficient use of the total capability of the computer complex. It must also maximize the real-time, on-line setup and test capabilities, make optimum use of core memory and provide a high-level programming and operational language. This has been accomplished for the EAI 690 Hybrid Computing System through a comprehensive software package that provides:

Problem Preparation
690 Hybrid FORTRAN
Symbolic Assembler with Linkage Instructions
HYTRAN Operations Interpreter

Setup and Checkout
Hardware Diagnostics
HYTRAN Operations Interpreter
690 Hybrid Debug

Operation
HYTRAN Operations Interpreter
Hybrid Programming Routines
a. Function Storage and Playback
b. Multi-variable Function Generation

690 HYBRID FORTRAN Real Time Features
The 690 Hybrid FORTRAN is composed of the ASA Standard FORTRAN IV compiler with a number of special features of real-time operation plus a complete system of hybrid linkage subroutines. The special features of real-time operation are:
Re-entrant subroutines
Mixed-mode arithmetic statements
Estimation of execution time
Delay statements
Interrupt masks set or reset by FORTRAN statements.

The provision of re-entrant subroutines is essential to permit the FORTRAN sub-routine program to be interrupted by a higher priority, and then completed once the interrupt has been processed.

The ability to use mixed-mode arithmetic statements permits the use of integer data derived from the analog-to-digital converter to be used in arithmetic expressions in combination with floating point digital variables.

The FORTRAN compiler relates the timing of execution of the digital program to the time base in the analog computer by estimating the execution time of any prescribed portion of the compiled code. This timing will be documented on the FORTRAN output listing.

The Delay statement of the 690 Hybrid FORTRAN instructs the compiler to provide for a waiting time of a fixed period after the execution of a block of computation is completed or a new program is begun. It is also possible to synchronize the digital program to a real-time base by means of an interrupt.

To permit the programming of the priority of the various interrupts, statements are provided for setting or resetting the interrupt mask bits in the Program Status Word of the 640. Control of the "mask" register associated with the general purpose interrupts terminated on the 680 console is performed by standard library subroutines.

Hybrid FORTRAN Linkage Subroutines
In addition to these real-time features, the 690 Hybrid FORTRAN includes a complete set of linkage subroutines to perform all of the operations available in the 690 linkage system. These subroutines are designed to operate in conjunction with the 690 Hybrid Debug to permit operation of the user's program independent of the linkage system. This is accomplished by trapping all input/output operations and transferring to the Debug program where all data and control inputs from the linkage system are simulated by tables of pseudo values. This information is then provided back to the user's program just as if the linkage system and the 680 were active.

Linkage Subroutine Library—Assembly Language
For the purpose of programming the digital portion of a hybrid problem in assembly language, a complete set of library subroutines are provided. These subroutines operate in conjunction with 690 Hybrid Debug to provide a hybrid operating system.

690 HYTRAN Operations Interpreter
The 690 HYTRAN Operations Interpreter is designed for use by scientists and engineers engaged in the preparation, setup, control, monitoring, and executions of hybrid computations. The HOI language was designed by EAI to integrate all of the capabilities of the 690 system so that the 680 analog components are treated in essentially the same fashion as digital variables. The most important function of HOI is to calculate and execute both potentiometer settings and the 680 static checks. This function is provided by HOI within the context of a powerful, general purpose, interactive hybrid programming language.

The HOI program permits immediate execution of algebraic and hybrid expression and the ability to retain a sequence of operations which may be executed under command of the user. The syntax of the algebraic language is similar to FORTRAN; however, the user specifications are as terse as possible to minimize the amount of typing. In addition to the integrated hybrid features, means are provided that facilitate user expansion of system capabilities to meet the ever-changing requirements of a hybrid environment.

690 Hybrid Debug

The most efficient method of checking out a hybrid problem is to initially check out the analog and digital programs independently and then combine the system for final checkout of the complete program. The HYTRAN Operations Interpreter provides a wide range of capabilities for setup and checkout of the analog portion of a hybrid problem. The 690 Hybrid Debug is the basic software package both for checkout of the digital program independently and for checkout of the combined system. Some of the specific hybrid features of the debug package used in conjunction with the linkage subroutines are:
The complete set of digital program debugging features

Complete I/O handling of the hybrid linkage system including error checking and documentation

Simulation of the linkage operations for independent checkout of the digital program

Monitoring and loading through the typewriter of all high speed data conversion channels

Setup and monitoring of all general purpose logic control and sense lines

Object time console selection

Reading coefficients and punchout of a specified block of potentiometer settings

Ability to accept a tape of pot settings and setup the analog computer

Processing of all Console Busy interrupts

Timing the actual execution of a specific portion of program

Assignment of one or more digital variables to specified DAC channels for conversion at fixed intervals of time.

Hybrid Programming Routines

The hybrid programming routines are an expandable system of software which includes certain basic packages plus additional hybrid applications programs which will be developed by EAI as well as other users of the EAI 690 system. The basic package which is provided with the 690 is composed of three routines that constitute a function manipulation system:
Arbitrary Function Generation
Function Storage and Playback.
Transport Delay.

The function generation routine generates arbitrary functions of one, two, or three variables. Any combination of analog arguments and multi-variable functions may be defined and the functional values may be readout to any specified DAC channels. The function values are updated on the basis of an interrupt from the 680 which may be driven by the digital timer or any other periodic timing signal generated on the logic section of the patch panel.

The program employs linear interpolation between the functional values stored at the specified breakpoints to determine the actual function value. An input program is provided which accepts the function definition in a convenient decimal format and stores the binary tables in memory.

The function storage and playback routine is used to store a sampled analog function in the 640 memory which is then played back to generate a continuous analog function in a subsequent analog run. The number of channels may be arbitrarily defined up to the limit of available conversion channels and the length of the tables may be entered as a parameter into the program. Provision is made to permit convenient initialization of the tables from either paper tape or values which have been stored on the disk. The functions may be readout without modification or may be readout and simultaneously updated from a new sampled function. The operation of both of these modes is determined by activating the appropriate interrupt from the logic section of the 680.

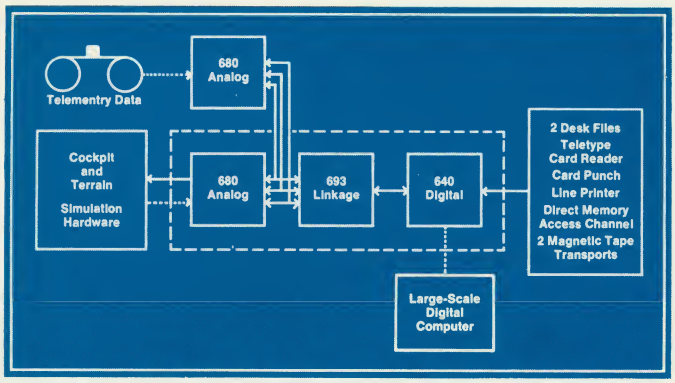
Transport delay is essentially a special case of function storage and playback where the memory table is operated in a circular fashion. Here the stored function is readout continuously during the run rather than on subsequent runs. Through a combination of variable table length and an arbitrary rate of updating the table, delays of any duration may be simulated. To obtain a variable delay, a simple logic circuit may be setup on the 680 to convert an analog variable (e.g. flow rate) to a proportional pulse rate.

Hardware Diagnostic Programs

A complete package of hardware diagnostic programs is provided to check the operation of the 640 digital computer, the hybrid linkage, and the 680 analog computer. The digital computer diagnostics consists of a program which exercises all of the instructions, memory, and each peripheral device. The hybrid linkage diagnostic is composed of a digital program which executes the checkout, monitors the results, and lists any difficulties. The program operates in conjunction with a hardwired patch panel which interconnects the general-purpose data and logic lines. The linkage diagnostic checks all three major sections of the linkage including interrupts.

An optional hardwired preventive-maintenance patch panel is also available for the EAI 680 analog system which exercises all of the patchable analog and logic components. This test is modularized into repetitions of a single basic circuit to permit rapid isolation of any faults.

EAI 690 APPLICATIONS



EAI 690 Hybrid Computing System In The Aerospace Industry

The Aerospace industry, from which hybrid computation developed, has successfully applied hybrid techniques to a wide range of problems. The spectrum of applications for hybrid computation in the Aerospace industry is very broad; however, it is possible to establish certain classes of problems which place rather specific demands on the simulation hardware. These classes are listed as follows: Aircraft Simulation / Short Range Missile Simulations / Helicopter (VTOL) Simulations / ICBM Simulations / Space Vehicle Mission Simulations / Telemetry Data Reduction

The first two categories can be handled by a medium scale hybrid system, such as the EAI 690 Hybrid Computing System, where the analog section solves the differential equations and the digital computer provides certain basic functions such as function generation. Helicopter simulations are somewhat more demanding due to the necessity of simulating the rotor characteristics so that a large scale digital computer in conjunction with a medium to large scale analog system may be required.

Complete ICBM and space vehicle mission simulations demand a large scale hybrid system; however, certain portions of a mission such as re-entry control optimization can be simulated on a medium scale hybrid system. Telemetry data reduction is a special case in which a medium scale hybrid system can perform the pre-processing of the data—including analog amplification, smoothing, etc., plus digital scaling (both linear and non-linear), and editing. The result is a magnetic tape of clean data arranged in convenient blocks for further processing, which can be done most efficiently by a large scale digital processor.

A proposed EAI—690 hybrid system configuration for the Aerospace industry is shown above. The analog portion consists of two fully expanded 680 computers which provides a 300 amplifier complement including the appropriate non-linear components. The EAI-640 can handle the digital computing functions of a large subset of the Aerospace simulation requirements. Most Aerospace laboratories also have access to a large scale central digital computer facility and a digital-to-digital link can be established to handle the sophisticated digital computation requirements of space vehicle simulations. In this case, the 640 would serve to control the 680s, perform the hybrid data conversion through the 693 linkage, and transfer blocks of data to/from the central digital computer.

A detailed description of the 690 System's component functions in this application is available on request.

EAI 690 Hybrid Computing System In Education

The presence of a hybrid computer in the university enables the faculty to investigate and evaluate the rapidly evolving techniques of electronic computation and simulation. Furthermore, the role of the hybrid computing facility is:

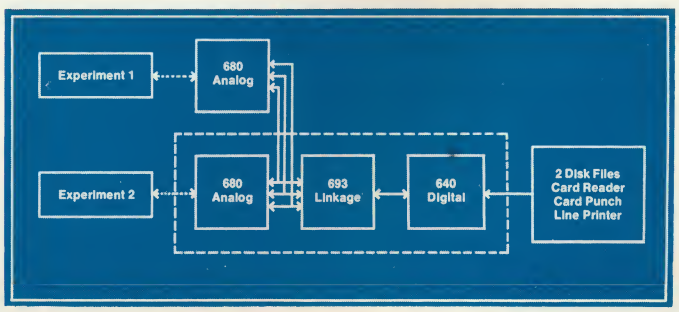
1. To provide equipment for the simulation of computer control of process and systems for graduate and faculty research, e.g., the kinetics and control of a chemical process.
2. To demonstrate to students the solution of significant problems by analog and hybrid techniques.
3. To provide a tool for instruction in formation processing and computer design courses.
4. To provide a tool for instruction in science and engineering courses that enables students to obtain a deeper understanding of the dynamic behavior of physical systems and phenomena.

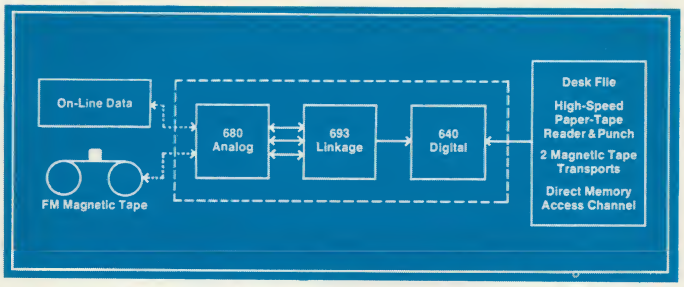
This diversity of requirements demands a very flexible system—such as the EAI 690 Hybrid Computing System—in which the analog and digital sections will often be used independently. A balanced 690 system specifically configured for the university requirements is shown below. The system is composed of two 680 consoles each approximately two-thirds expanded, a powerful 640 system, and medium size linkage. This will permit two medium scale analog simulations to proceed independently, or one hybrid study plus one analog program, or one large hybrid simulation using both 680's. The relatively large core memory in the 640 will permit the university to make most effective use of the comprehensive digital and hybrid software provided with the 690 system as well as more extensive use of the 640 as an independent digital computer.

Since the hybrid computer serves a number of purposes in nearly all departments of the university, it is difficult to classify specific applications. The 680 can be used to simulate most systems which are represented by a set of ordinary differential equations. In this case, the 640 may be used to automate the setup and checkout of the analog program. For problems in which the physical system is represented by partial differential equations, the entire hybrid computer will generally be used. Some studies, such as aerospace vehicle simulation, may be represented by a mathematical model which is composed of a set of ordinary differential equations—in which case the portion demanding high accuracy will be computed on the 640 and the lower accuracy computations will be performed on the 680.

Of course, the 640 may be used for any type of stored program digital processing independent of the analog computer and linkage system.

A detailed description of the 690 System's component function in this application is available on request.





The EAI-690 in Bio-Medical Engineering

The hybrid computer is a very effective tool for both data analysis and physiological simulation in the Life Science field and its use has been increasing rapidly. The hybrid computer offers an automatic means for correlating the results of these simulations to actual data. For example, using a hybrid computer it is possible to simulate the cardiovascular system, cause the "patient" to have a heart attack, observe the results and automatically relate this simulation to real EKG data in memory storage. It enables the bio-medical researcher to do in the laboratory that which would otherwise be impractical, impossible or dangerous. Furthermore, complex experiments and analyses can be made more rapidly and more thoroughly than before, due to the automatic capabilities of the system.

The EAI 690 Hybrid Computing System configuration above is based on surveys of existing systems in the field and the applications to which they are applied, and a knowledge of bio-medical applications gained from EAI Computation Center experience.

In bio-medical simulations, a mathematical model represents the physical process in the living organism—which demands a close interaction between the bio-engineer and the computer. This capability was one of the major design criteria for the 690 hardware and software.

EKG or EEG data is usually recorded from sensors directly onto FM magnetic tape. Therefore, the source of data for computer processing is the analog outputs from this type recording. The analog computer (EAI 680) is particularly effective in preprocessing this data to filter out undesirable noise signals. In conjunction with patchable logic elements the analog can also perform a variety of relatively simple data analysis functions—such as sensing the start of an event, calculation of probability distributions, spectral separation of the signal, etc.

This analysis may be done "on-line", i.e., during surgery. In such event, the digital computer (EAI 640) would accept preprocessed analog data, plus certain logic signals through the linkage system (EAI 693) to further reduce the data. If standard statistical techniques such as auto and cross-correlation are used, the final results can be displayed on a scope via digital-to-analog converters in the 693. If pattern recognition techniques are employed, the digital computer can indicate the status of the patient directly.

Display of this status in the operating room permits immediate remedial action when necessary. The data may also be recorded on digital magnetic tape for future processing.

A detailed description of the 690 System's component functions in this application is available on request.

The EAI-690 in Chemical Process Industry

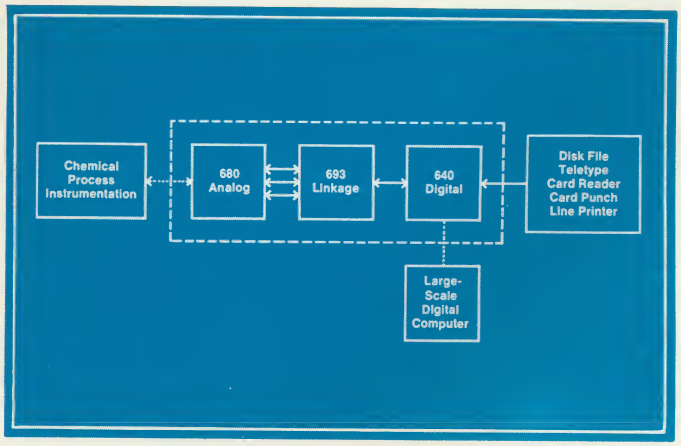
Hybrid computers have proven to be both convenient and economical tools for the solution of a wide range of problems in the chemical and petroleum field. Analog computers have been used for many years in the simulation of chemical processes; however, the pure analog approach imposes restrictions on the size of the system which can be simulated. The cost of a digital simulation often exceeds the marginal savings which may result from the study. Furthermore, digital simulation lacks the man-machine-problem interaction provided by analog or hybrid computers. Thus Hybrid computers have proven to be both convenient and economical tools for the solution of a wide range of problems in the chemical and petroleum fields.

The primary applications have been in the design and optimization of process control systems where a chemical process is simulated by the analog computer and functions such as transport delay, complex functions or digital control system is represented by a digital program. A common difficulty in the simulation of a chemical or nuclear reactor is providing an adequate representation of the transport of fluid in pipes from one point to another—from reactor to heat exchanger. The simulation of this transport delay of a dynamic variable, such as the time variation of the fluid temperature, is accomplished by the use of the digital computer; the digital memory stores the temperature function for a fixed or variable length of time. By simulating systems such as chemical reactors, heat exchanges, and distillation columns, studies on design feasibility, maximum yield and minimum cost become economically practical.

A representative configuration of the EAI 690 Hybrid Computing System for use in chemical process problems is shown below. Based on research conducted prior to the design of the 690, this system will satisfy virtually all of the problems encountered in chemical engineering for which a hybrid computer has been used.

The 690 permits simulation of a control system's performance as the real physical system actually performs; that is, analog devices are represented on the 680 analog/hybrid system, and if the control is to be by a digital computer—the 640 digital system will be used to design the control program.

A detailed description of the 690 system's component functions in this application is available on request.



EAI SUPPORT

The availability of support services from the manufacturer is essential to the successful operation of a large-scale computing laboratory. Such support should not only assure the satisfactory operation of the computer, but provide for its full utilization as an effective problem-solving tool as well. EAI has incorporated this basic philosophy into a complete program of customer support activities to assist the user in maintaining equipment, in training personnel, and in applying new computing techniques to the solution of scientific and engineering problems. Continued support of this type has been largely responsible for the high degree of customer acceptance of EAI Computing System.

Services fall into two general categories: those associated with training, applications assistance, software design and maintenance and computer time rental, and those associated with maintenance, repair service, and availability of replacement parts. Each of these functions is assigned to a specific department in the EAI organization to assure the customer of immediate response to requests.

For those services requiring an extensive knowledge of the programming and application of computing equipment, EAI maintains and operates a number of Computations Centers in the United States and Europe that offer equipment rental, applications assistance, training, and systems analysis. A complete staff of experienced engineering and scientific personnel is available at each location to analyze technical problems, interpret scientific data, and provide complete engineering assistance to customers. These personnel are also available to conduct training programs at customer installations and to assist in the programming and operation of EAI computing equipment.

EAI has established a large network of regional service engineering offices and parts depots throughout the world. Each of the regional locations is equipped to provide rapid and efficient service to guarantee maximum use of EAI computing equipment. Trained service engineering personnel are available at each office to supply emergency service when needed. EAI also offers a variety of maintenance programs under which EAI personnel will assume complete responsibility for the maintenance of customer equipment, or will serve to supplement the customer's own maintenance staff.

Inter-related operations in research, engineering, manufacturing and marketing activities makes it possible for EAI to provide this extensive back-up support—support that is available only from a major manufacturer of electronic equipment. This complete technical capability and EAI's exceptionally high standards of quality stand behind every EAI computing system—assuring the customer of complete and professional support in the operation of his computation facility.

EAI®

ELECTRONIC ASSOCIATES, INC. *West Long Branch, New Jersey 07764*

ADVANCED SYSTEMS ANALYSIS AND COMPUTATION SERVICES/ANALOG COMPUTERS/DIGITAL COMPUTERS/HYBRID ANALOG-DIGITAL COMPUTATION EQUIPMENT/ANALOG AND DIGITAL PLOTTERS/SIMULATION SYSTEMS/SCIENTIFIC AND LABORATORY INSTRUMENTS/INDUSTRIAL PROCESS CONTROL SYSTEMS/PHOTOGRAMMETRIC EQUIPMENT/RANGE INSTRUMENTATION SYSTEMS/TEST AND CHECK-OUT SYSTEMS/MILITARY AND INDUSTRIAL RESEARCH AND DEVELOPMENT SERVICES/FIELD ENGINEERING AND EQUIPMENT MAINTENANCE SERVICES.

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67001

EAI® applications reference library

January 1967

This is your new index to the EAI Applications Reference Library. It has been arranged as follows:

1. Ordering numbers are also publication reference numbers which enable the user to catalog papers according to:

   a. Field of Interest

   b. Type of Paper

   c. Type of Computation

A key to this system appears on the following page.

2. New publications will be categorized according to the following computations:

   a. General Purpose Analog — papers which deal only with applications for the general purpose analog computer.

   b. Hybrid — papers which describe applications requiring both general purpose analog and general purpose digital computers.

   c. Analog/Hybrid — publications describing uses for the general purpose analog computer with parallel digital logic.

We have included ordering cards so that you may conveniently request any or all publications which are available.

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Bulletin Number AL 66473-1

KEY TO INDEX

Subject	Index No.
General Section	1.0.0
General Applications	2.0.0
Aerospace	3.0.0
Bio-Medical	4.0.0
Business/Economics	5.0.0
Chemical/Petro-Chemical	6.0.0
Educational	7.0.0
*Educator's Demonstration Series	7.6.0
Electrical/Electronics	8.0.0
Instrument/Controllers	10.0.0
Mechanical	11.0.0
Metals Processing	12.0.0
Nuclear	13.0.0
Other	20.0.0

Type of Paper	Second Numeral
Surveys	.1
Abstracts	.2
Notes	.3
Studies	.4
Bibliographies	.5

Type of Computation	Suffix
Analog — applications for the general purpose analog computer.	a
Hybrid — applications requiring both general purpose analog and general purpose digital computers.	h
Analog/Hybrid — applications requiring the general purpose analog computer with parallel digital logic.	a/h

*Added since previous issue, August 1966. The series enables educators to use the analog computer to demonstrate to students the dynamic behavior of physical systems. These demonstrations serve to animate textbook material, heightening student interest while providing a means for deeper understanding of physical phenomena.

EAI® applications reference library

INDEX January 1967

Title	Order No.
General Analog Section — 1.0.0a	
Primer on Analog Computation -- Computing Techniques	1.1.2a
A Practical Approach to Analog Computers -- Computing Techniques	1.3.1
Continuous Data Analysis with Analog Computers Using Statistical and Regression Techniques -- Computing Techniques	1.3.2a
Simple Analog Computer Oscilloscope Displays -- Application Study	1.3.6a
In Other Sections See: **Solution of Mathieus' Equation on the Analog Computer -- Application Study**	7.4.4a
General Analog/Hybrid Section — 1.0.0a/h	
Automatic Iterative Operation on an Analog Computer -- Computing Techniques	1.3.4a
Automatic 3-D Displays with the TR-48/DES-30 Desk-Top Hybrid Computer System -- Computing Techniques; (Synopsis of 1.3.5a, below.)	1.2.5a
Automatic 3-D Displays with the TR-48/DES-30 Desk-Top Hybrid Computer System -- Computing Techniques	1.3.5a
TR-48/DES-30 Hybrid Implementation of Correlation Functions -- Computing Techniques	1.3.7a
Automatic Time Mark Generation on the TR-48/DES-30 Desk-Top Hybrid Computer System -- Computing Techniques	1.3.8a

January 1967, supersedes previous issue dated August 1966.

Title	Order No.
General Analog/Hybrid Section — 1.0.0a/h (continued)	
TR-48/DES-30 Hybrid Simulation of Space Vehicle Attitude Control System -- Computing Techniques	1.3.9a
General Hybrid Section — 1.0.0h	
Spectrum of Applications for the Modern Hybrid Computer -- Computing Techniques	1.1.1h
System Response Analysis with the Analog Memory and Logic System -- Application Notes; (Synopsis of 1.3.4h, below.)	1.2.4h
System Response Analysis with the Analog Memory and Logic System -- Computing Techniques	1.3.4h
Two Variable Function Generator Program for HYDAC® -- Application Notes; (Synopsis of 1.3.6h, below.)	1.2.6h
Two Variable Function Generator Program for HYDAC -- Application Study	1.3.6h
The Simulation of Transport Delay with the HYDAC Computing System -- Application Notes; (Synopsis of 1.3.7h, below.)	1.2.7h
The Simulation of Transport Delay with the HYDAC Computing System -- Computing Techniques	1.3.7h
Applications of Analog Storage Techniques for Hybrid Computation -- Application Notes; (Synopsis of 1.3.8h, below.)	1.2.8h
Applications of Analog Storage Techniques for Hybrid Computation -- Computing Techniques	1.3.8h
Trigonometric Resolution Program for HYDAC -- Application Notes; (Synopsis of 1.3.10h, below.)	1.2.10h

Title	Order No.
General Hybrid Section - 1.0.0h (Continued)	
Trigonometric Resolution Program for HYDAC -- Application Study	1.3.10h
Hybrid Programming: A Comprehensive "Software" Package for HYDAC -- Application Notes; (Synopsis of 1.3.13h, below.)	1.2.13h
Hybrid Programming: A Comprehensive "Software" Package for HYDAC -- Computing Techniques	1.3.13h

January 1967, supersedes previous issue dated August 1966.

Title	Order No.
General Applications — 2.0.0a	
Analog Computation for Optimization Problems -- Application Notes	2.3.1a
General Applications — 2.0.0h	
Arithmetic Operations with the HYDAC Digital Operations System -- Application Notes; (Synopsis of 2.4.1h, below)	2.3.1h
Arithmetic Operations with the HYDAC Digital Operations System - Application Study	2.4.1h
Hybrid Computer Techniques for Determining Probability Distributions -- Application Note; (Synopsis of 2.4.2h, below)	2.3.2h
Hybrid Computer Techniques for Determining Probability Distributions -- Applications Study	2.4.2h

Title	Order No.
Aerospace — 3.0.0a	
In Other Sections See: TR-48/DES-30 Hybrid Simulation of Space Vehicle Attitude Control -- Computing Techniques	1.3.9a
Aerospace — 3.0.0h	
Simulation of a Space Vehicle with Reaction Jet Control System -- Application Notes; (Synopsis of 3.4.1h, below)	3.3.1h
Simulation of a Space Vehicle with Reaction Jet Control System -- Application Study	3.4.1h
HYDAC Simulation of a Terrain Avoidance Flight Control System -- Application Notes; (Synopsis of 3.4.2h, below)	3.3.2h
HYDAC Simulation of a Terrain Avoidance Flight Control System -- Application Study	3.4.2h
Hybrid Simulation of an Aircraft Adaptive Control System -- Application Notes; (Synopsis of 3.4.5h, below)	3.3.5h
Hybrid Simulation of an Aircraft Adaptive Control System -- Application Study	3.4.5h
Radar Simulation and Video Conversion using Hybrid Computing Techniques -- Application Notes; (Synopsis of 3.4.7h, below)	3.3.7h
Radar Simulation and Video Conversion using Hybrid Computing Techniques -- Application Study	3.4.7h
NASA-Ames Hybrid Computer Facilities and Their Applications to Problems in Aeronautics -- Application Notes; (Synopsis of 3.4.8h, below)	3.3.8h
NASA-Ames Hybrid Computer Facilities and Their Application to Problems in Aeronautics -- Application Study	3.4.8h

January 1967, supersedes previous issue dated August 1966.

Title	Order No.
Aerospace — 3.0.0h (Continued)	
Hybrid Simulation of a Temperature Rate Flight Control System for Re-entry Vehicles -- Application Notes; (Synopsis of 3.4.13h, below)	3.3.13h
Hybrid Simulation of a Temperature Rate Flight Control System for Re-entry Vehicles -- Application Study	3.4.13h

Title	Order No.
Bio-Medical — 4.0.0a	
A Survey of Accomplishments in Bio-Engineering -- Survey	4.1.1a
Digital and Analog Computation Considerations for Bio-Medical Problems - Survey	4.1.2a
A CO_2 Rebreathing Study -- Application Notes; (Synopsis of 4.4.2a, below)	4.3.2a
A CO_2 Rebreathing Study: The Determination of CO_2 Partial Pressure During Rebreathing -- Application Study	4.4.2a
Analog Computer Simulation of the Cardiovascular System of the Fetal Lamb -- Application Study	4.4.3a
A Host-Parasite Problem -- Application Study	4.4.4a
A One-Organ Chemotherapy Model -- Application Notes	4.3.5a
An Analog Program for Electroencephalographic Data Analysis -- Application Study	4.4.6a
On-Line Computation of Cardiac Output from Dye Dilution Curves -- Application Notes	4.3.7a
A Simple Analog Computer Program to Calculate Membrane Permeability Coefficients for Water -- Application Study	4.4.8a
In Other Sections See:	
Respiratory Control System -- Application Study	7.4.3a
The Human Pupil Servomechanism -- Application Study	7.4.7a

Title	Order No.
Bio-Medical — 4.0.0h	
Hybrid Computer Analysis of Electrocardiographic Data -- Application Notes; (Synopsis of 4.4.1h, below)	4.3.1h
Hybrid Computer Analysis Electrocardiographic Data -- Application Study	4.4.1h

Title	Order No.
Business/Economics - 5.0.0a	
Modelling Dynamic Economic Problems on the Analog Computer -- Survey	5.1.1a

Title	Order No.
Chemical/Petro-Chemical — 6.0.0a	
A Survey of Analog Computer Uses in the Chemical and Process Industries -- Survey	6.1.1a
Analog Computer Study of a Semi-Batch Reactor -- Application Notes; (Synopsis of 6.4.7a, below)	6.3.7a
Analog Computer Study of a Semi-Batch Reactor -- Application Study	6.4.7a
The Many Faces of Analog Computation -- Application Abstract	6.2.18a
Combined Feedforward/Feedback Control of a Chemical Reactor -- Application Study	6.2.19a
In Other Sections See:	
Investigation of a Simple Chemical Reaction -- Application Study	7.4.2a
Calculation of the Radial Velocity of a Rotary Spray Drier -- Application Study	7.4.6a
Simulation of a Reciprocating Compressor -- Application Study	11.4.1a
Chemical/Petro-Chemical — 6.0.0h	
The Hybrid Simulation of a Chemical Tubular Reactor -- Application Notes; (Synopsis of 6.4.1h, below)	6.3.1h
Development of a Program for the Hybrid Simulation of a Tubular Reactor -- Application Study	6.4.1h
Hybrid Simulation of a Control System for a Tubular Chemical Reactor -- Application Notes; (Synopsis of 6.4.2h, below)	6.3.2h
Hybrid Simulation of a Control System for a Tubular Chemical Reactor -- Application Study	6.4.2h

January 1967, supersedes previous issue dated August 1966.

Title	Order No.
Educational — 7.0.0a	
A Man-Machine Control System Illustrating an Application of "Quickening" -- Application Study	7.4.1a
Investigation of a Simple Chemical Reaction -- Application Study	7.4.2a
Respiratory Control System -- Application Study	7.4.3a
Solution of Mathieus' Equation on the Analog Computer -- Application Study	7.4.4a
Three-Mode Controller -- Application Study	7.4.5a
Calculation of the Radial Velocity of a Rotary Spray Drier -- Application Study	7.4.6a
The Human Pupil Servomechanism -- Application Study	7.4.7a
Investigation of Heat Transfer by Conduction -- Application Notes	7.3.8a
Motion of Coupled Pendula -- Application Study	7.4.9a
Three-Mode Control of Heat Exhanger -- Application Notes	7.3.10a
Simulation of Oxygen Dynamics Relative to Purification of Fresh Water -- Application Study	7.4.11a
Application of Desk-Top Computers as Aids in Teaching Mathematics -- Application Study	7.4.12a
* Educator's Demonstration Series	
Forward	7.6.0
An Introduction to Computer Simulation	7.6.1a
Why Simulate Linear Systems?	7.6.2a
Vibrations	7.6.3a
Analog Computers and Mathematics	7.6.4a

*Added since previous issue dated August 1966.

Title	Order No.
Educational — 7. 0. 0a (Continued)	
*Nonlinear Relaxation Oscillations	7. 6. 5a
*Free-Fall Trajectories with Square Law Drag	7. 6. 6a
In Other Sections See:	
A Host-Parasite Problem -- Application Study	4. 4. 4a
Pulse Transformer Circuit and Pulse Forming Network -- Application Notes	8. 3. 5a
Investigation of the Output Response of a Positional Servo System -- Application Notes	8. 3. 6a

*Added since previous issue dated August 1966.

Title	Order No.
Electrical/Electronics — 8.0.0a	
An Analog Computer Study of the Transient Behavior of a High-Speed Tunnel-Diode Switching Circuit -- Application Notes; (Synopsis of 8.4.3a, below)	8.3.3a
A Study of the Transient Behavior of a High-Speed Tunnel-Diode Switching Circuit Using an Analog Computer -- Application Study	8.4.3a
Pulse Transformer Circuit and Pulse Forming Network -- Application Notes	8.3.5a
Investigation of the Output Response of a Positional Servo System -- Application Notes	8.3.6a
Non-Linear Resonance -- Application Notes	8.3.7a
In Other Sections See: Solution of Mathieus' Equation on the Analog Computer -- Application Study	7.4.4a

Title	Order No.
Instruments/Controllers — 10.0.0a	
In Other Sections See: A Man-Machine Control System Illustrating an Application of "Quickening" -- Application Study	7.4.1a
Three-Mode Controller -- Application Study	7.4.5a

January 1967, supersedes previous issue dated August 1966.

Title	Order No.
Mechanical — 11.0.0a	
Simulation of a Reciprocating Compressor -- Application Study	11.4.1a
An Analog Computer Cumulative Damage Program -- Application Study	11.4.2a
In Other Sections See: **Motion of Coupled Pendula -- Application Study**	7.4.9a

Title	Order No.
Metals Processing — 12.0.0a	
See: Three-Mode Control of Heat Exchanger -- Application Notes	7.3.10a

Title	Order No.
Nuclear — 13.0.0a	
Simulation of the Primary Loop of a Nuclear Power Plant with a Small General Purpose Analog Computer -- Application Notes; (Synopsis of 13.4.2a, below)	13.3.2a
Simulation of the Primary Loop of a Nuclear Power Plant with a Small General Purpose Analog Computer -- Application Study	13.4.2a
A Study of Xenon Poisoning -- Application Notes: (Synopsis of 13.4.3a, below)	13.3.3a
A Study of Xenon Poisoning in a Nuclear Reactor -- Application Study	13.4.3a